Neoclassical theory of pedestal flows and its comparison with C-Mod measurements

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Conventional neoclassical theories are essentially built upon the original ion orbit evaluation by Galeev and Sagdeev, which assumes that scale-length of background quantities such as the plasma density or electrostatic potential are much larger than the orbit width. For the main ion species, this assumption is found to break down in many pedestal experiments. The pedestal width is often comparable to the poloidal ion gyroradius and the variation of electrostatic energy over an ion orbit is then comparable to the ion's kinetic energy. As a result, the pedestal flow of main ions can be substantially different from its core counterpart.

The short background scale of the pedestal does not have a similar impact on individual motion of impurity ions and electrons. The former usually have a high charge number and collide before drifting a distance comparable to their poloidal gyroradius. The latter's poloidal gyroradius is much less than that of the ions and therefore the pedestal width. However, both electron and impurity ion species experience friction with background ions and therefore their flows are modified as well. The associated discrepancy for the poloidal impurity flow has been measured to be substantial for the banana regime H-mode pedestal of Alcator C-Mod [1].

We evaluate main ion orbits accounting for the radial electric field inherently present in a subsonic H-mode tokamak pedestal. We are then able to carry out the kinetic calculation to find pedestal modifications to the conventional neoclassical prediction for the banana regime main ion flow [2]. This result, in turn, allows us to deduce the pedestal expressions for the poloidal impurity flow and the bootstrap current. We then proceed by comparing the revised formula for the impurity flow with the boron flow measured in banana regime C-Mod pedestals to find that agreement between the theory and experiment is noticeably improved upon accounting for the electric field effect on the main ion orbits [3]. This comparison verifies the role of the electric field in modifying the main ion flow and supports our conclusion that the bootstrap current is enhanced in a banana regime pedestal [4].

[1] K.D. Marr et al, 2010 *Plasma Phys. Control. Fusion* **52** 055010
[2] G. Kagan and P.J. Catto 2010 *Plasma Phys. Control. Fusion* **52** 055004
[3] G. Kagan et al, 2011 *Plasma Phys. Control. Fusion* **53** 025008
[4] G. Kagan and P.J. Catto 2010 *Phys. Rev. Lett.* **105** 45002